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Geospatial Assessment of Flood Vulnerability Areas in Lagos Metropolis, Nigeria

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ABSTRACT

Flooding is now a common event in Nigeria, causing harm to both people and infrastructure progress. Areas with lower elevations are more significantly impacted by floods. Twenty (20) LGAs in Lagos are currently being evaluated to pinpoint areas at risk of flooding to better manage flood risks and reduce the impact of natural disasters. This research seeks to evaluate specific flood-prone locations on the map of Lagos using GIS technology and provides important recommendations to mitigate the effects of flooding in those regions. Research indicates that areas like Epe, Badagary, Eti-Osa, and Ibeju-Lekki are at a high risk of flooding, whereas Ifako-Ijaiye, Agege, Alimosho, Ikeja, Mushin, Shomolu, Lagos Mainland, and Ajeromi/Ifelodun have a lower vulnerability to floods. Hence, it is recommended that regions susceptible to flooding consistently check water levels in the rainy season and release water from reservoirs to avoid property damage and loss of life. Moreover, further measures include enhancing environmental knowledge for locals in flood-prone regions and engaging government agencies and the community in community-driven flood risk management. The findings and recommendations of this research are expected to be implemented to prevent potential disasters in the most flood-prone areas of Lagos.

Keywords: Flooding; Flood risk areas; Flood management; Community resilience; Vulnerability; Disaster management; Water level monitoring; Infrastructure; Mitigation; Geographic information system.

1. Introduction

Flooding has emerged as a significant global problem endangering human security, particularly in terms of sustainable food production [1]. Floods are posing a growing danger to food security. Fifty percent of flood-related fatalities worldwide have been identified as happening in Asia [2]. Floods result in extensive devastation, causing significant socioeconomic and environmental harm to human lives, buildings, assets, and agricultural areas, causing immense distress to impacted communities. Disasters impede the advancement of sustainable development as well as food security and growth. The rising losses from natural disasters such as floods are having a greater effect on underdeveloped countries [3]. They destroy the quality of life and the possibilities for progress in general.

Recognizing the significance of disaster prevention and management in reducing food insecurity caused by flood disasters, the World Bank is shifting its focus from traditional relief and reconstruction towards promoting preventative measures for sustainable development [5]. This new strategy is more dependent on sharing knowledge, establishing communities of practice, and raising awareness in disaster risk management for government officials, civil society, and flood-prone local communities. There is sufficient evidence indicating that the increase in flood-related disasters and subsequent food insecurity is connected to the heightened vulnerability of individuals globally. The increase in flooding disasters was caused by the chosen course of human development.

Also important to note was the acknowledgment that this rise in susceptibility was not consistent. The occurrence of flooding in Nigeria has been rising. In September of 2010, heavy rainfall began in Lagos and neighbouring states, resulting in severe flooding in flood-prone areas of Lagos that caused both human and material losses. The riverbanks were overwhelmed due to the heavy rainfall, worsened by the water released from dams and inadequate drainage. 1.5 million individuals were forced to flee due to the disaster, resulting in numerous deaths and extensive

damages to farmland, crops, and property valued at millions of Naira [5]. Disasters are not perceived as only occurring due to natural occurrences but rather because of the interaction between hazards and vulnerability with minimal coping capacity [6].

This paper seeks to evaluate areas in Lagos prone to flooding and provide recommendations to minimize flood consequences in those places.

1.1. Study Objectives

(i) To analyse and map the flood-prone areas in Lagos using Geographic Information System (GIS) technology.

(ii) To identify and categorize the 20 LGAs in Lagos based on their vulnerability to flooding, with a focus on both high-risk and low-risk areas.

(iii) To develop a spatial database of flood-prone areas, incorporating topographical data, historical flood records, and current land use patterns.

(iv) To evaluate and recommend the implementation of regular water level monitoring during the rainy season in vulnerable regions.

(v) To propose the establishment of a systematic water release mechanism from reservoirs to mitigate flood risks.

1.2. Basic Idea of Hazards and Disasters

A natural disaster occurs when a natural hazard such as a flood, tornado, hurricane, volcanic eruption, earthquake, or landslide occurs. It leads to financial, environmental, or human harm. The extent of damage is determined by how well a community can withstand the danger, known as resilience. This idea is captured in the statement: "Disasters arise when vulnerabilities intersect with hazards [7]. Natural disasters will not occur in areas that are not vulnerable to natural hazards, such as strong earthquakes in uninhabited regions [8]. The concept of nature has been questioned, as these events are not considered hazards or disasters unless humans are involved [9].

To identify hazards in a community, hazard analysis is necessary. This involves systematically investigating potential disasters by examining their history, vulnerability, and probability, as defined by [10]. They also characterized hazard identification as a methodical process for identifying hazards that present a substantial risk to the local authority. According to the United Nations, a disaster is considered "major" when the affected areas are unable to handle it adequately and need assistance from other countries. This typically occurs when the death toll reaches thousands or displaced individuals' number in the hundreds of thousands, or when the total financial damage or insurance claims are exceptionally high.

Clearly, most natural disasters are unavoidable, but strategies to minimize their impact can be highly successful. Furthermore, measures can be implemented to eliminate or decrease the effects of a disaster to a minimal level. Man's need to farm, industrialize, and urbanize has caused extensive and uncontrolled tree cutting, gas flaring, and fossil fuel usage, resulting in environmental pollution, global warming, and a rise in floods. It was mentioned that a combination of geospatial techniques, remote sensing, and geographical information systems is necessary to gather information on hazardous areas or environments.

1.3. The Concept of Flood

Flooding occurs when water levels rise due to heavy rainfall, a dam breaking, increased river, ocean, or sea volume from melting ice caps, or continuous rain, leading to overflow and affecting surrounding areas. The level and nature of water volume can determine the danger of floods. When running water is called "flood," it typically suggests a risk or calamity. Certainly, floods have led to significant financial damages, disturbances, and fatalities. Khatri-Chatri et al. [11] argue that floods were responsible for the highest proportion of economic losses and deaths among all types of natural disasters in the late 1980s and 1990s.

As stated by Abimbola et al. [12], floods have the most benefits and drawbacks compared to any other environmental hazard. Abimbola et al. [12] contend that they have always been a natural occurrence, with individuals attempting to exploit them for their own benefit as much as they can. Floods are essential for preserving and reviving the valuable services offered by wetland ecosystems along rivers and deltas like those formed by the Nile in Egypt and the Niger in Nigeria.

The advantages of flooding, as stated by Wisner et al. [7], consist of providing essential habitats for fish, waterfowl, and wildlife; supporting a wide variety of plants and animals; renewing nutrients in agricultural soil; and carrying sediments to preserve downstream deltas and coastal regions. For a considerable period, these flood-prone areas have been appealing to agriculture, fishing, and hunting settlements, as well as, more recently, tourism initiatives. Improved soil fertility benefits agriculture, while nutrient-rich waters enhance fishing opportunities in ponds, lakes, lagoons, and river channels. The scenic beauty and diverse flora and fauna of the area attract tourism. Various types of floods exist, such as riverine floods, tsunamis, coastal floods, tidal floods, man-made floods, and flash floods.

2. The Study Area

The city of Lagos is situated between the Lagos mainland and the Atlantic Ocean [9]. The research area is located on the southwest coast of Nigeria, roughly between latitudes 6°22'N and 6°52'N and longitudes 2°42'E and 3°42'E (figs. 1 and 2). Lagos is close to the Republic of Benin to the west and the 180-kilometer Atlantic coast to the south. Ogun State borders it to the north and east. The study area covers 3,577 square kilometers, with around 22 percent of it being water. Metropolitan Lagos makes up around one-third of Lagos State, covering 455 sq. Several kilometers of the city consist of water bodies, wetlands, and mangrove swamps.

2.1. Flood Prone Areas in Lagos State

The elevation of Lagos State varies from 77 meters (above sea level) to 25 meters (below sea level). The top elevation can be found in Alimosho LGA, with other high elevations in Ifako/Ijaiye (76 m), Ikorodu (70 m), Ikeja (68 m), and Agege (65 m) within the state. Lagos Island is home to the state's lowest altitude, which sits 25 meters below sea level.

Each local government was given an estimate of land area measurement in places highly susceptible to flooding. Eti-osa LGA has the largest proportion of land at high risk with 79.38%, with Ajeromi/Ifelodun following at 66%. 28.78% of the state's total land area, which is 961.13 km2 out of 3339.94 km2, is considered at a high risk of flooding.

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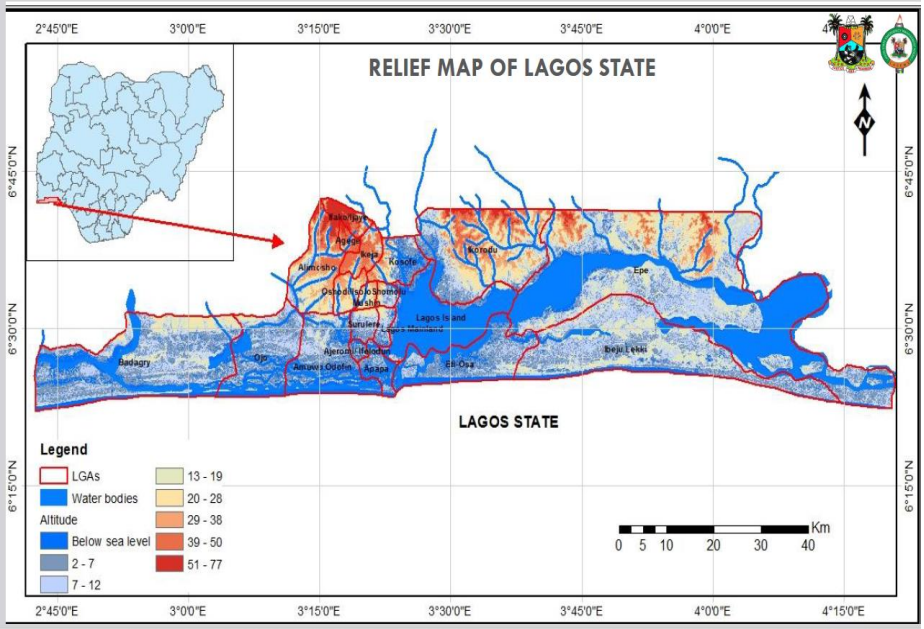

Figure 1. Relief map of Lagos State

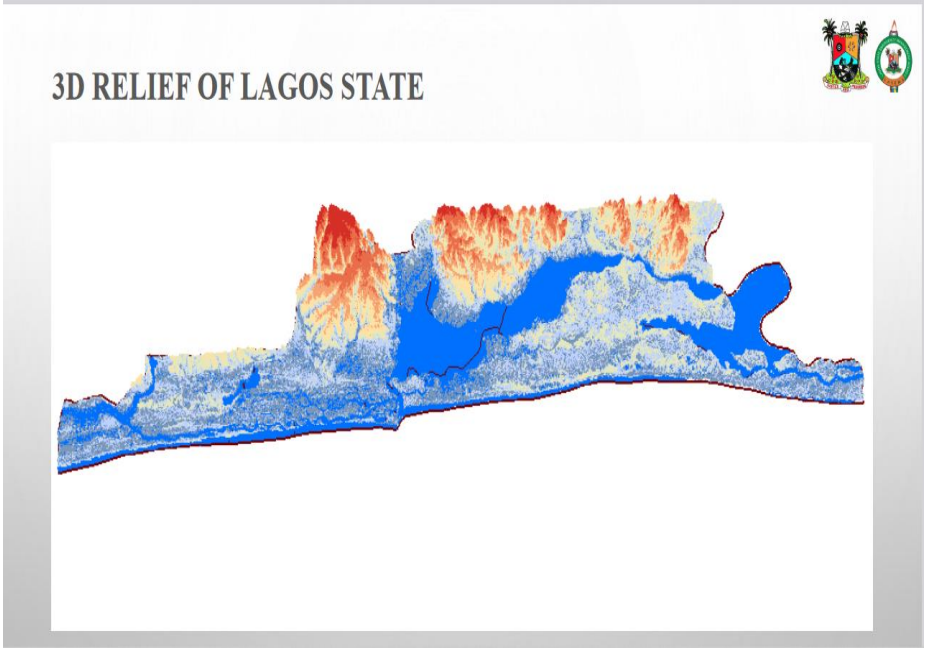

Figure 2. 3D Relief of Lagos State

3. Methodology

An evaluation and mapping of flood vulnerability and risk have been carried out in all local governments of the state to reduce the effects of floods. Mapping is essential for disaster prevention and will help the organization issue timely alerts, organize effectively, and promptly react to disasters. The evaluation used a mix of remote sensing information and geographic information systems.

4. Result and Discussion

Assessing twenty (20) LGAs in Lagos to assess flood-prone areas is crucial for efficient flood risk management to reduce the impact of natural disasters. Table 1, in addition to Fig. 3–8, demonstrates the different categories of flood

risk in Lagos State, Nigeria, including high, moderate, and low-risk areas. Epe, Badagary, Eti-Osa, and Ibeju-Lekki are designated as flood-prone areas with a higher risk of experiencing flooding disasters. Conversely, Ifako-Ijaiye, Agege, Oshodi, Alimosho, Ikeja, Mushin, Shomolu, Lagos Mainland, and Ajeromi/Ifelodun are classified as low-risk flood zones. Places such as Kosofe, Ikorodu, Ojo, Amuwo-Odofin, Apapa, Lagos Island, and Surulere have a moderate chance of experiencing flooding.

Table 1. Land Area (km) of the LGAs at High, Moderate & Low Risk of Flood

S/N	LGAs	Land area at high flood risk (km)	Total land area (km)	% of land area at high flood risk
1	Ifako- Ijaiye	0.18	33.62	0.54
2	Agege	0	16.58	0
3	Alimosho	7.27	148.06	4.91
4	Ikeja	0.84	45.74	1.84
5	Kosofe	35.55	74.12	47.96
6	Oshodi	1.45	38.6	3.76
7	Mushin	0.5	17.39	2.86
8	Shomolu	4.46	18.3	24.37
9	Ikorodu	45.67	363.68	13.56
10	Epe	143.42	875.2	16.39
11	Badagry	194.38	516.53	37.63
12	Ojo	86.11	196.58	43.8
13	Amuwo-Odofin	94.24	173.38	54.35
14	Surulere	12.03	30.72	39.16
15	Lagos Mainland	8.41	22.78	36.92
16	Ajeromi/ Ifelodun	7.76	11.65	66.61
17	Lagos Island	29.31	82.79	35.4
18	Apapa	19.91	32.9	60.52
19	Eti-Osa	133.59	168.3	79.38
20	Ibeju-Lekki	136.05	473.02	28.77

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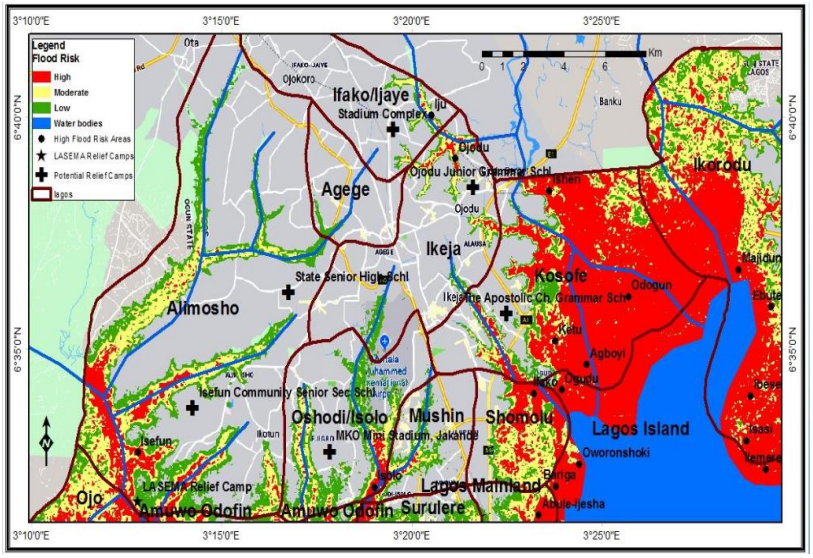

Figure 3. Map shows flood area of Alimosho, Agege, Ifako/Ijaiye, Ikeja, Kosofe, Oshodi, Mushin, and Shomolu

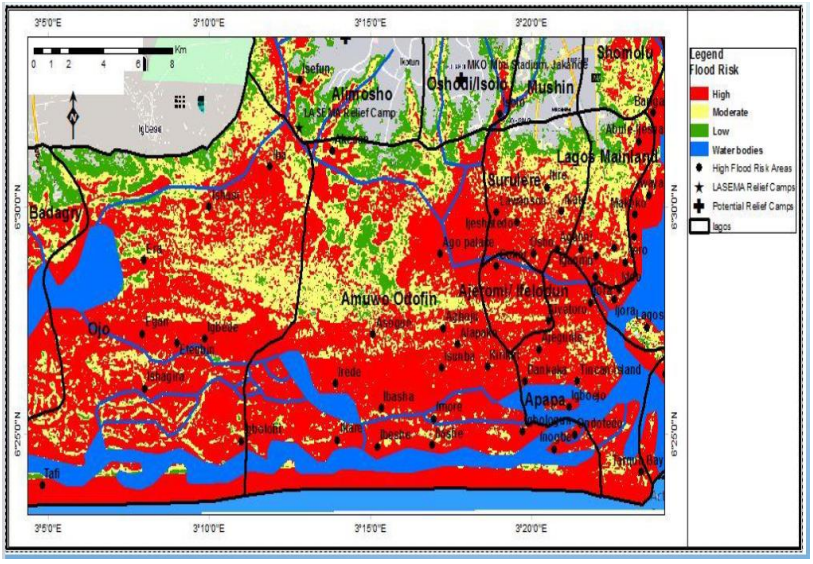

Figure 4. Map shows flood area of Ojo, Amuwo Odofin, Surulere, Lagos Mainland, Ajeromi/Ifelodun and Apapa

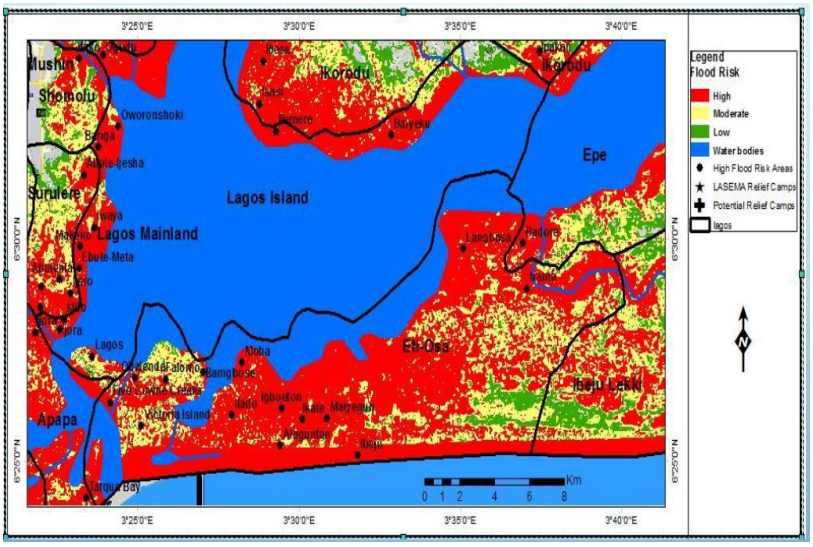

Figure 5. Map shows flood area of Eti-Osa and Lagos Island

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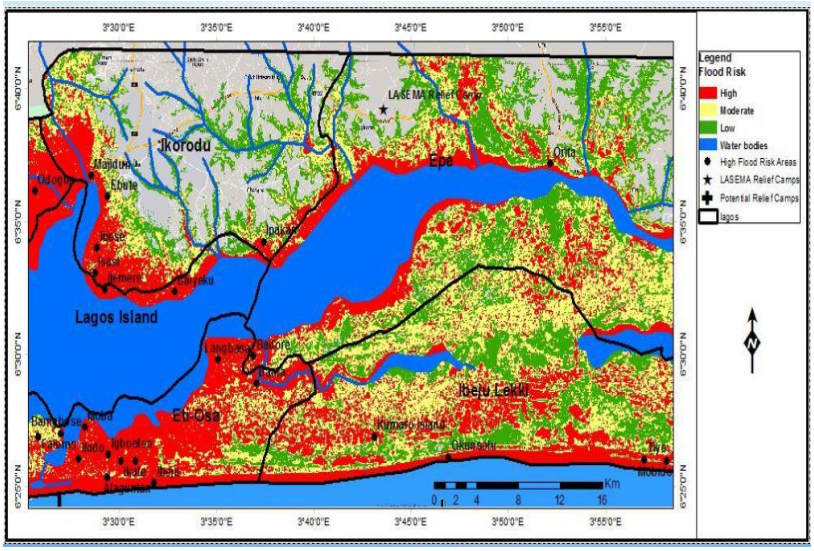

Figure 6. Map shows flood area of Ikorodu and Epe

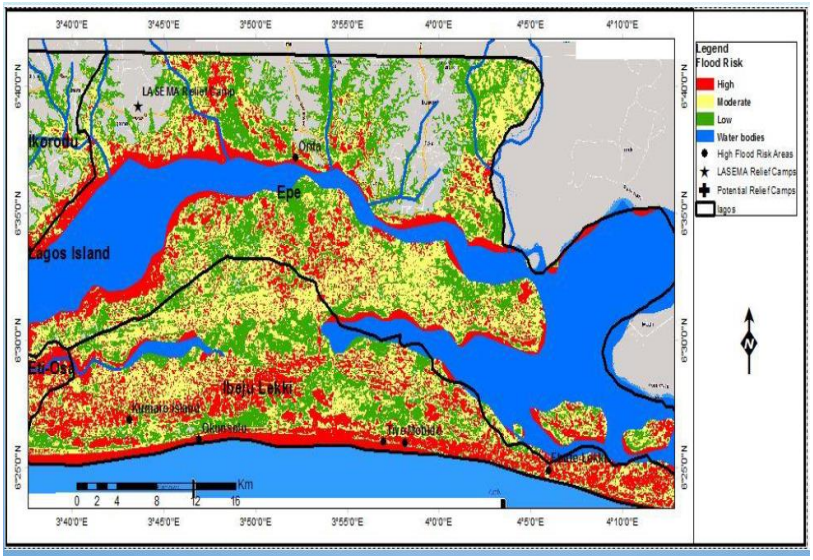

Figure 7. Map shows flood area of Ibeju-Lekki

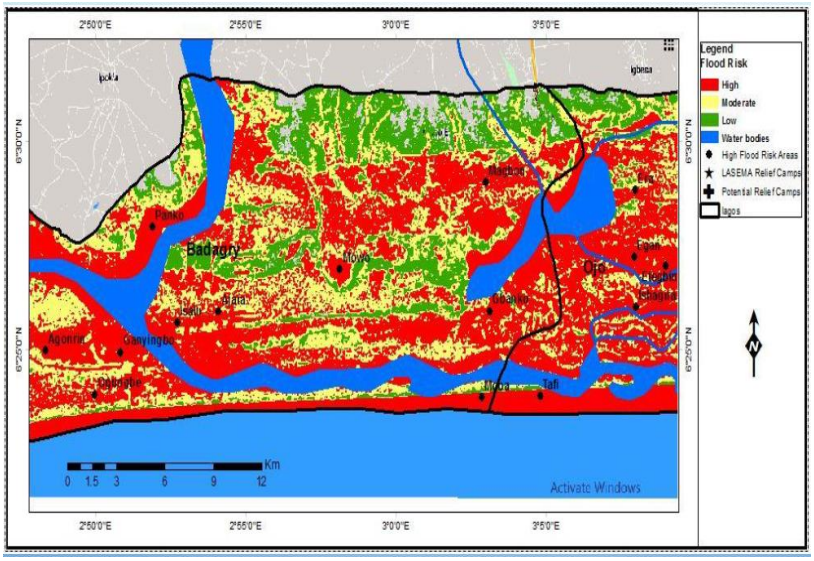

Figure 8. Map shows flood area of Badagry

5. Strategy for Managing Flood Risks Integrated

To develop efficient strategies for managing and controlling floods from the start, it is crucial to consider factors like the length of the flood, its extent, the speed of the water flow, and the amount of water released over a specific period. The length of a flood plays a crucial role in determining the time needed for an area to disperse or eliminate peak water levels. Some floods have rapid changes in water levels, while others remain high for several days. Having knowledge about this is crucial for planning and implementing flood control strategies. Moreover, it is essential to gather data on flood occurrence and its speed, which is the rate at which floodwater moves. This is usually decided by evaluating how far flood water travels in relation to how long it flows [13]. Flooding happens because of a mix of natural elements and actions by people. Human activities, such as deforestation, urbanization in flood-prone areas, and insufficient flood control efforts, contribute to the effects of natural events such as heavy rainfall, storms, soil conditions, and climate change impacts [14]. Because of the increasing risk of floods and their harmful effects on the population and infrastructure, it is essential to establish an integrated flood risk management strategy to better address the ongoing problem of flooding across the country. Structural and non-structural actions can lessen the effects of floods. Structural measures consist of funding the strategic building of new dams, reservoirs, and river channels and restoring failing infrastructure such as river basins, drainage systems, embankments, and shorelines. Non-structural measures consist of implementing policies, enacting legislation, and establishing regulations to guarantee the appropriate upkeep, administration, and function of flood control structures, as well as laws safeguarding river shorelines and embankments.

6. Conclusion

This study points out that the primary causes of flooding in areas with high and moderate flood risks include water release from dams, intense precipitation, and proximity to lagoons. Local officials must include areas with high and moderate flood risks in the dissemination of flood alerts to enhance flood prevention measures, guaranteeing that residents grasp vital infrastructure and prevent casualties and damage. The government must collaborate with the community to initiate the establishment of efficient community warning systems to assist the people. This system is crucial in helping communities dealing with flood disasters efficiently handle flood risk. Before releasing the water from the dam, it is crucial to issue an early alert within the community. Creating an extensive network of big drainage systems to divert water to the river can effectively address the issue of flash floods in the area. Government disaster management agencies are responsible for visiting and interacting with communities to identify local resources for flood relief projects and encourage community participation. Residents of the areas must receive instruction on flood prevention methods using casual techniques in the beginning, specifically targeting vulnerable households in their own dialect. This will improve the community's capacity to address difficulties.

The recommendations presented in this paper form an integrated flood risk management strategy. The goal is to address the problem of frequent flooding in Lagos and utilize this resource for the country's social, economic, agricultural, and power generation benefits.

The following suggestions should be taken into consideration to avoid any future disasters in the flood vulnerability areas in Lagos metropolis, Nigeria.

(i) Firstly, invest in real-time monitoring and early warning systems to provide timely alerts to residents.

(ii) Secondly, develop community-based programs that involve locals in flood preparedness and response, enhancing resilience.

(iii) Thirdly, improve and maintain infrastructure like drainage systems and levees to manage floodwaters.

(iv) Lastly, foster collaboration between government agencies, NGOs, and communities to create sustainable flood management solutions. This comprehensive approach ensures safety, resilience, and optimal use of water.

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The author declares no competing financial, professional, or personal interests.

Consent for publication

The author declares that he consented to the publication of this study.

Authors' contributions

Author’s independent contribution.

Availability of data and material

Supplementary information is available from the author upon reasonable request.

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